Today's World in Space

I Want to Fly the Shuttle

I Want to Fly the Shuttle


NASA
STOP
BEYOND THIS POINT
1. REMOVE ALL PERSONAL ITEMS FROM THE UPPER POCKETS.
2. WEAR BADGES INSIDE SHIRT OR CARRY IN PANTS POCKET.
3. REMOVE WATCHES AND RINGS OR TAPE SAME.
4. EYE GLASSES MUST BE TETHERED.
5. ALL TOOLS MUST BE TETHERED.
6. ACCESS RESTRICTED WITHIN 3 FT. OF VEHICLE. CONTACT ACCESS CONTROL MONITOR

Today's World in Space

I Want to Fly the Shuttle

By David Baker

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CONTENTS

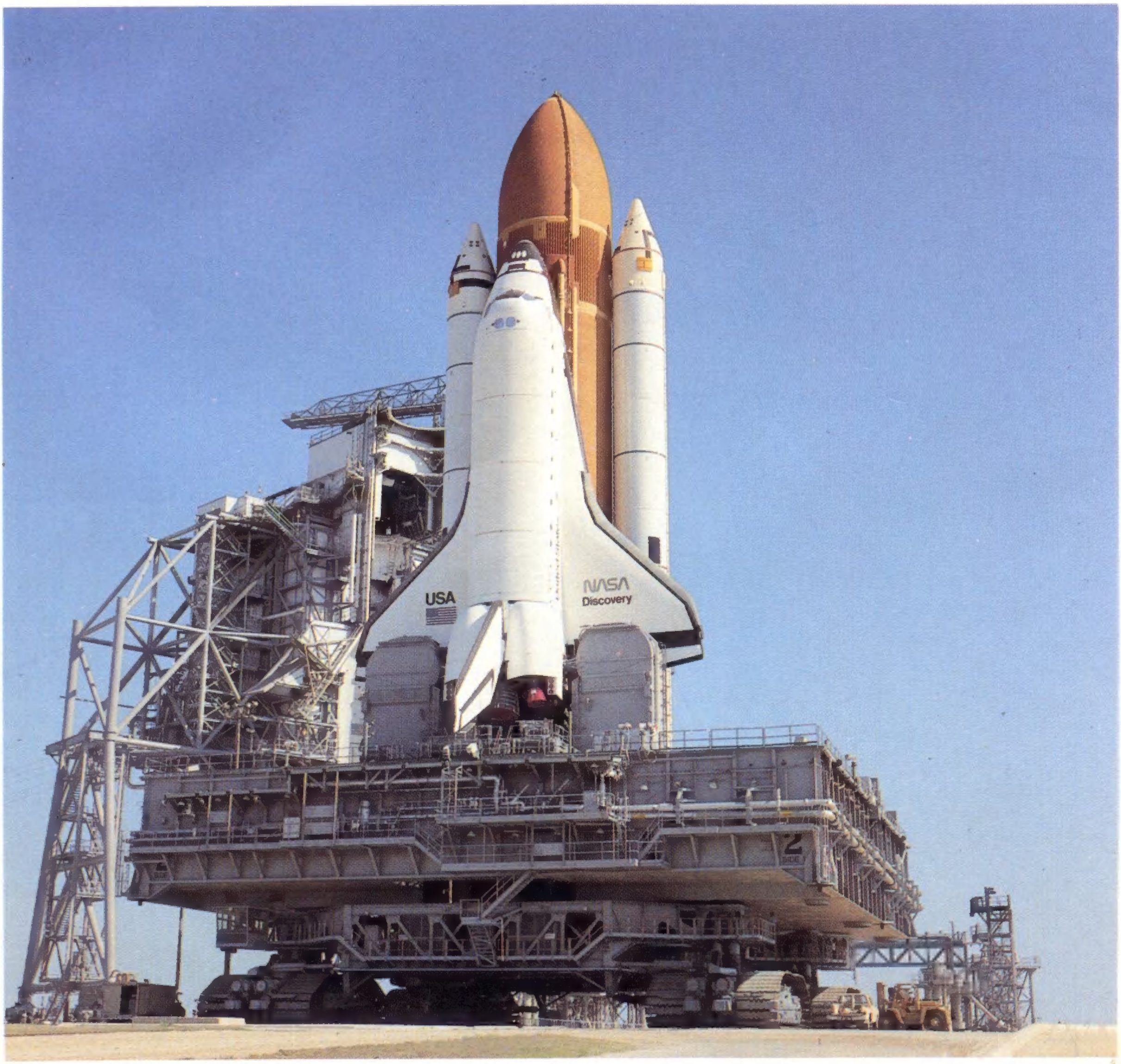
1	What is the Shuttle?	6
2	How to be an Astronaut	14
3	The Flight Deck	24
4	Flying the Shuttle	30
5	Return to Earth	40
	Glossary	46
	Index	47

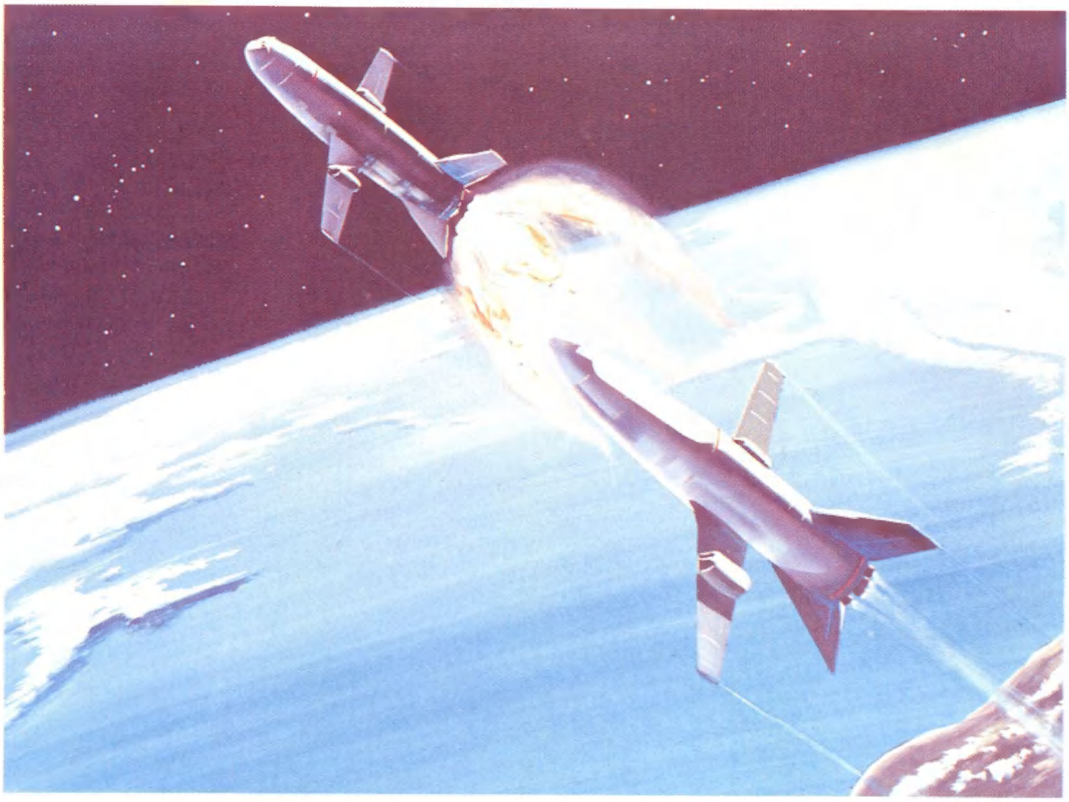
What Is the Shuttle?

The shuttle is the world's first reusable spaceplane. It has been built to help cut the cost of sending humans into space. It is also capable of returning to Earth with large and heavy cargo loads. Above all, it helps men and women do bigger and better things in space. Without it, astronauts would not have as much room to work and would not be able to repair satellites, build space stations, or carry out scientific experiments.

Space travel is expensive for two reasons. The cost of equipment is high, and rockets are thrown away after one use. Only the shuttle comes back to land like an airplane. Only three

The NASA shuttle is the world's first reusable spaceplane, designed to carry cargo into orbit and down again.





At first, engineers thought they would develop a shuttle with a booster like an airplane. Both the booster and the orbiter would be piloted.

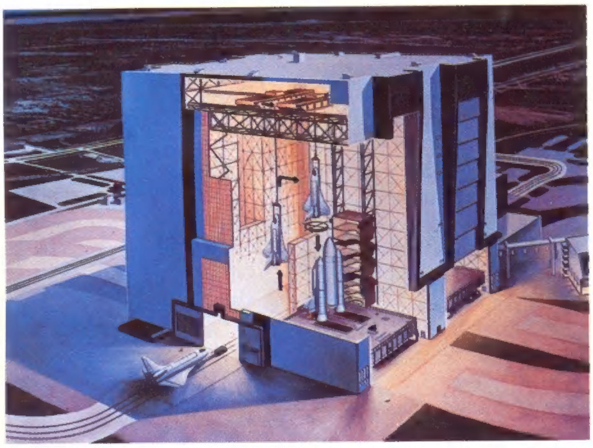
or four shuttle vehicles are needed to launch most United States satellites. Each shuttle has been built to make at least 100 flights into space. By keeping the equipment and using it again and again, costs are kept down and only a few vehicles are necessary.

The shuttle is the first of its kind. Engineers spent a long time designing it, because they were not adapting an old design but creating a completely new vehicle. They worked carefully to come up with a design that was not only reusable, but also safe and reliable.

Not everything always goes right, however, and the space shuttle *Challenger* blew up during launch on January 28, 1986. One of its booster rocket joints leaked. Engineers are certain they know what went wrong, and they have made corrections to prevent that from happening again. But NASA engineers can never be completely sure that the shuttle is completely accident-free. For that reason, various safety features have been built in to restrict the damage caused by unexpected problems.

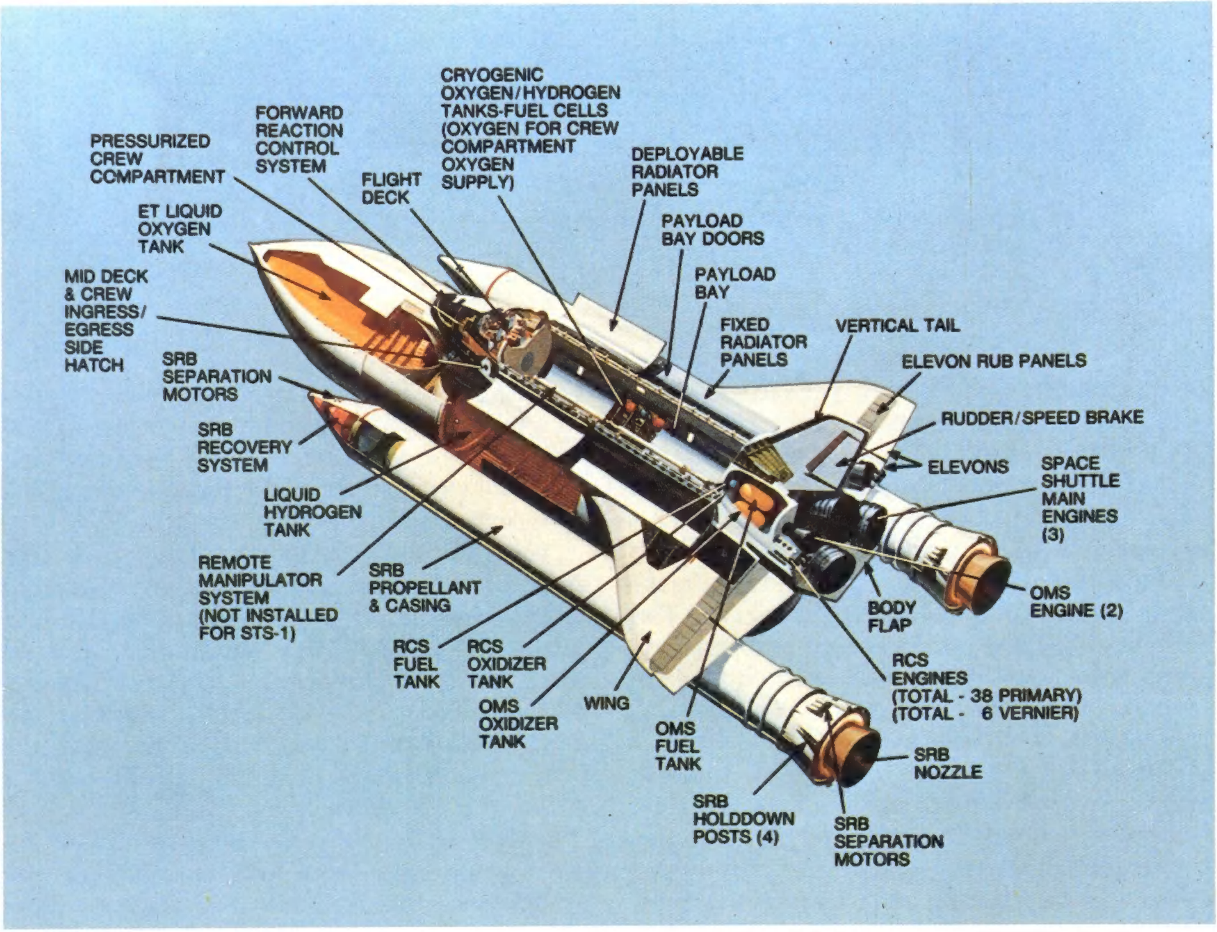
When NASA officials first looked at reusable space-planes, they had a wide variety of designs to choose from. Their goal was to build a fully reusable system. They envisioned a huge rocket-powered airplane that would carry an *orbiter* on its back toward space. Launched vertically, the orbiter would separate from the booster at a height of about 42 miles and a speed of 6,250 MPH.

In that design, both the booster and the orbiter would have been fully reusable. Yet the system was complex, with two separate flight crews in the booster and orbiter and two



Left: The shuttle is assembled in a huge vehicle assembly building, where the orbiter is brought and attached to an external tank and two big solid rocket boosters.

Below: The shuttle is made up of a winged reusable orbiter, a big external tank containing hydrogen and oxygen to power the three main engines in the orbiter, and two huge solid rocket boosters designed to thrust it on its way for the first two minutes of flight.

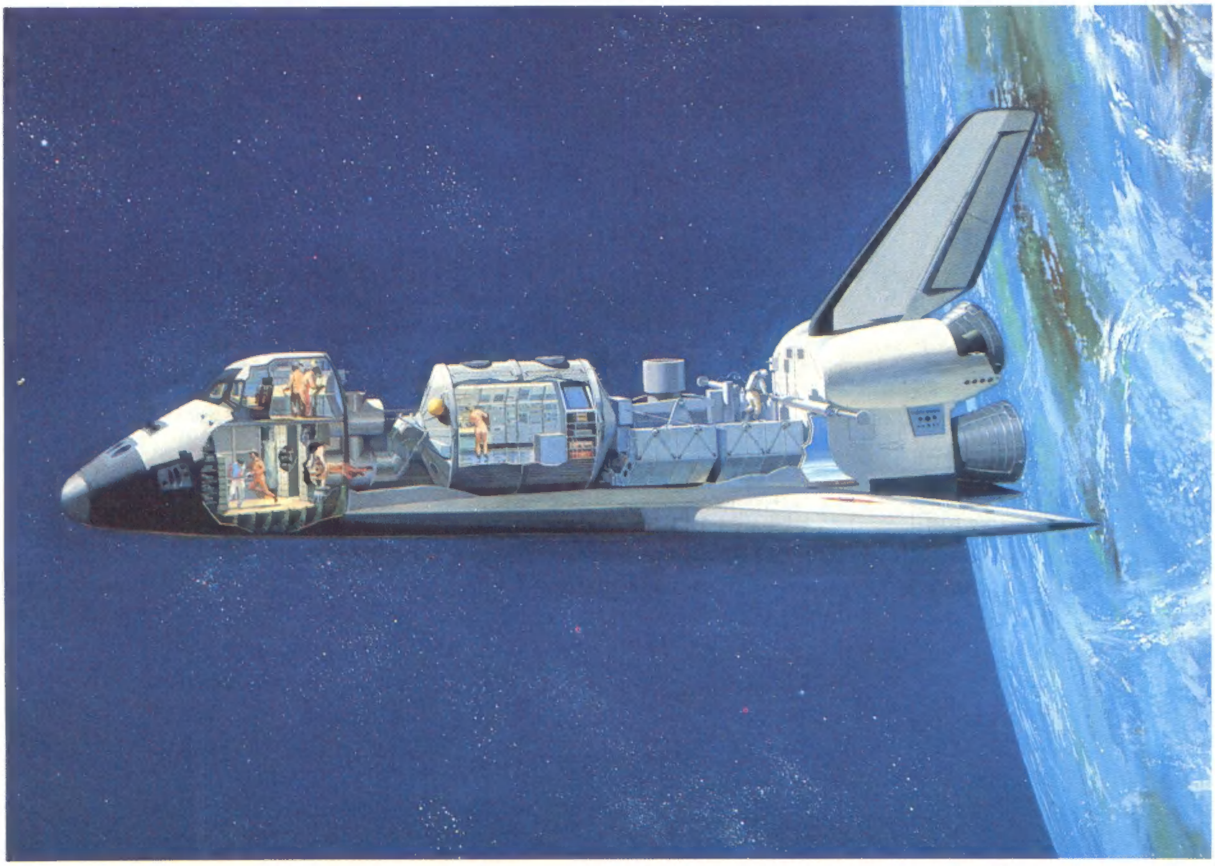


vehicles to land instead of one. Moreover, the cost was very high, and NASA was unable to afford it. So the engineers went back to their drawing boards to design something simpler and less costly.

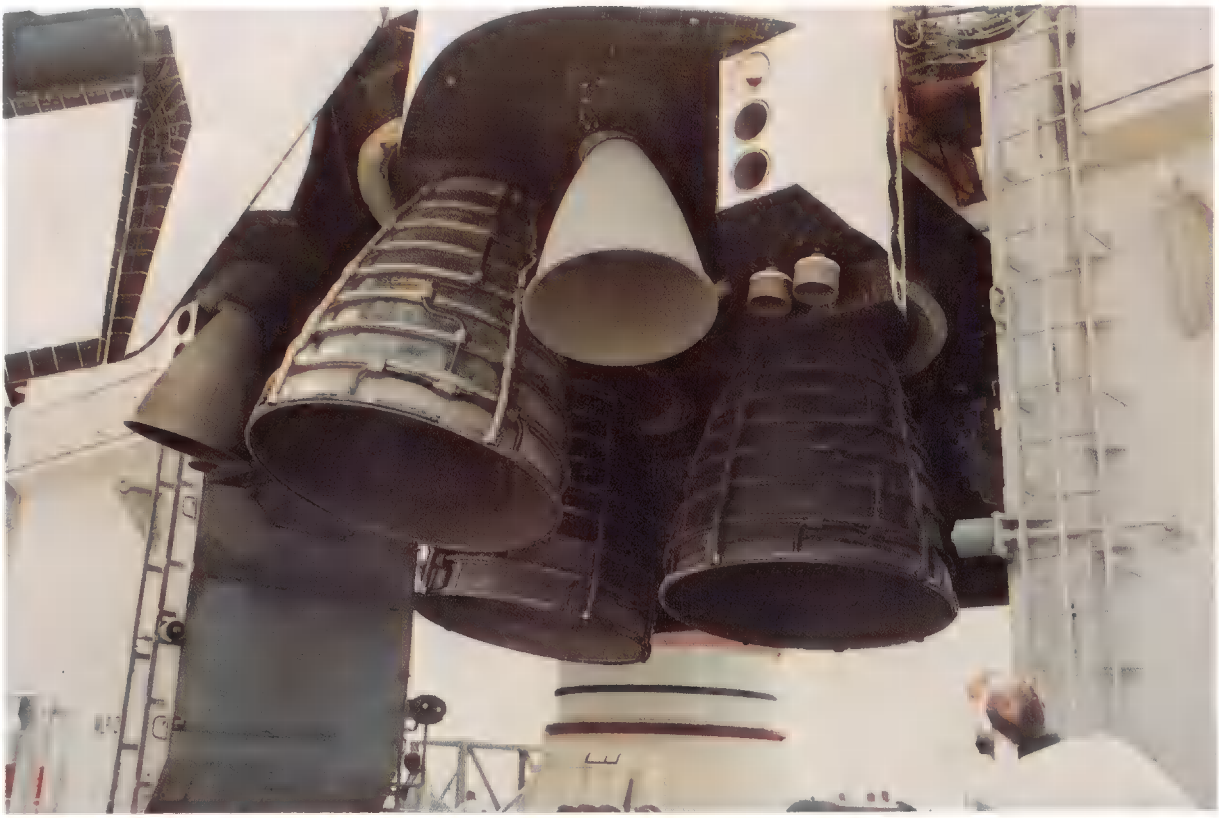
What they came up with was a compromise. Instead of carrying the orbiter to a height of more than 40 miles before starting its own rocket motors, why not ignite those motors on the pad? And instead of building a huge booster with wings, why not attach to the orbiter two smaller boost motors that can be jettisoned on the way up? The booster could parachute back down into the sea and be recovered for another flight.

That design looked more realistic, and in 1972 the program got under way. The two boosters would use solid propellant instead of complex motors burning liquid fuels. They could be used on as many as 20 missions. Though smaller than a manned booster with wings and liquid fuel rockets, they would be bigger than any previous solid motor ever built. That would help lift the orbiter to height of 28 miles and a speed of just over 3,000 MPH.

NASA built five orbiters. The first, *Enterprise*, was ready by 1977. It was used in drop tests from the back of a modified Boeing 747 Jumbo Jet. Flown down to a landing at NASA's Dryden Flight Research Center in California, the *Enter-*



The shuttle is capable of carrying large quantities of cargo inside its 60-foot by 15-foot payload bay. It can also carry a laboratory like this European Spacelab.



The three big shuttle main engines are only used during the flight up into orbit. The two smaller engines (the white bell-shaped nozzles) are used for maneuvers and for slowing the spacecraft down in its return to Earth.

prise proved that the shuttle could be controlled to a perfect landing at the end of a long space mission. Because no one had built a shuttle before, this landing success was an important step toward first flight.

Enterprise would never fly into space. It was too heavy and served as an air test vehicle only. The second shuttle, *Columbia*, was ready by 1979 and made its first flight on April 12, 1981. It used the same launch pad, modified for all the shuttles, that Apollo astronauts had used to fly to the moon. The next shuttle was *Challenger*. It made its first flight in April, 1983, and was followed by *Discovery* in August, 1984, and *Atlantis* in October, 1985.

In all, 24 successful shuttle flights had taken place when *Challenger* was sent on its tenth mission on January 28, 1986. It blew up just 73 seconds later, and the fleet of shuttles was grounded until the faulty booster joint design had been changed. A replacement for *Challenger* is being built and will be ready to join *Columbia*, *Discovery* and *Atlantis* in 1991. Meanwhile, the three remaining shuttles will resume flights sometime in late 1988.

On the pad, the fully fueled shuttle weighs more than 2,200 tons, almost as much as a small warship. The orbiter itself weighs about 115 tons, including 30 tons of cargo in its payload bay. The orbiter is 122 feet long and has

All shuttles are launched from one of two converted pads, originally built for Apollo moon landing missions between 1969 and 1972.

a wing span of 78 feet. The cargo bay, 60 feet long and 15 feet wide, takes up most of its length. The crew compartment is located forward of the payload bay, with the big engine compartment behind it and below the tail.

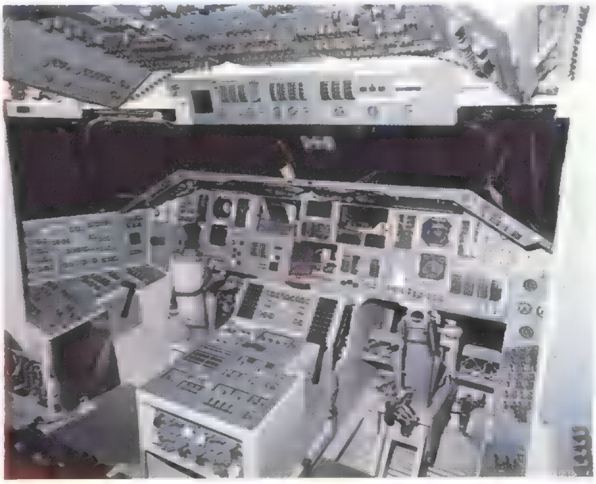
The three main engines are reusable and can be throttled to control the amount of thrust they produce. At maximum throttle, the three engines deliver a total 730 tons of thrust. The shuttle gets lighter as it climbs higher and burns fuel, so the engines are progressively throttled back. They burn liquid hydrogen and liquid oxygen, one of the most efficient combinations of propellant available.

The engines get propellant from a huge *external tank*, 154 feet long with a diameter of 27 feet, 6 inches. It weighs 33 tons and contains 795 tons of hydrogen and oxygen. On average the engines burn these propellants at a rate of nearly 2 tons a second. The orbiter is attached to the side of the external tank, and two pipes 17 inches in diameter carry hydrogen and oxygen

The big external tank is used to carry hydrogen and oxygen for the engines at the rear of the orbiter. The two big boosters carry solid propellant, and they fire for just over two minutes.

to the engines of the shuttle.

The two *solid rocket boosters* (SRBs) are the largest ever flown, although smaller boosters of the same basic design are used with Air Force Titan launches. Each SRB is 149 feet long, with a diameter of just over 12 feet, and each weighs about 90 tons empty. The boosters are made in segments and stacked together for launch. The solid propellant is not hard, but flexible like an eraser. It is poured into each segment with a hole left in the middle. Then it is left to dry. When all the boosters segments are attached to each other the holes line up to make a tunnel from the top to the bottom.



The orbiter is designed to be flown very much like an airplane, although it is computer-controlled during launch and re-entry.

Fueled boosters stacked for launch each weigh around 645 tons. Together, they make up more than half the shuttle's launch weight. They shed this weight at an enormous rate during launch. To start the boosters, a flame is ignited inside at the top. It instantly spreads the full length of the tunnel, running down the center of each booster. The propellant continues to burn from the center out toward the steel walls. In their 2 minutes of operation, the boosters burn off almost 9 tons of solid fuel each second.

When the orbiter reaches space, it weighs only a fraction of its weight on the launch pad. In the first 8 minutes before getting into orbit, the shuttle discards more than 2,000 tons of tank, booster cases, and the liquid and solid propellant they contain. Only the external tank is dumped and not used again. It separates from the orbiter just before the shuttle nudges into orbit using small maneuvering motors on each side of the tail. The empty tank burns up in the atmosphere.

Shuttle orbiters are ferried around on top a converted Boeing 747 airliner specially equipped to carry the 80 ton spaceplane.

How to Be an Astronaut

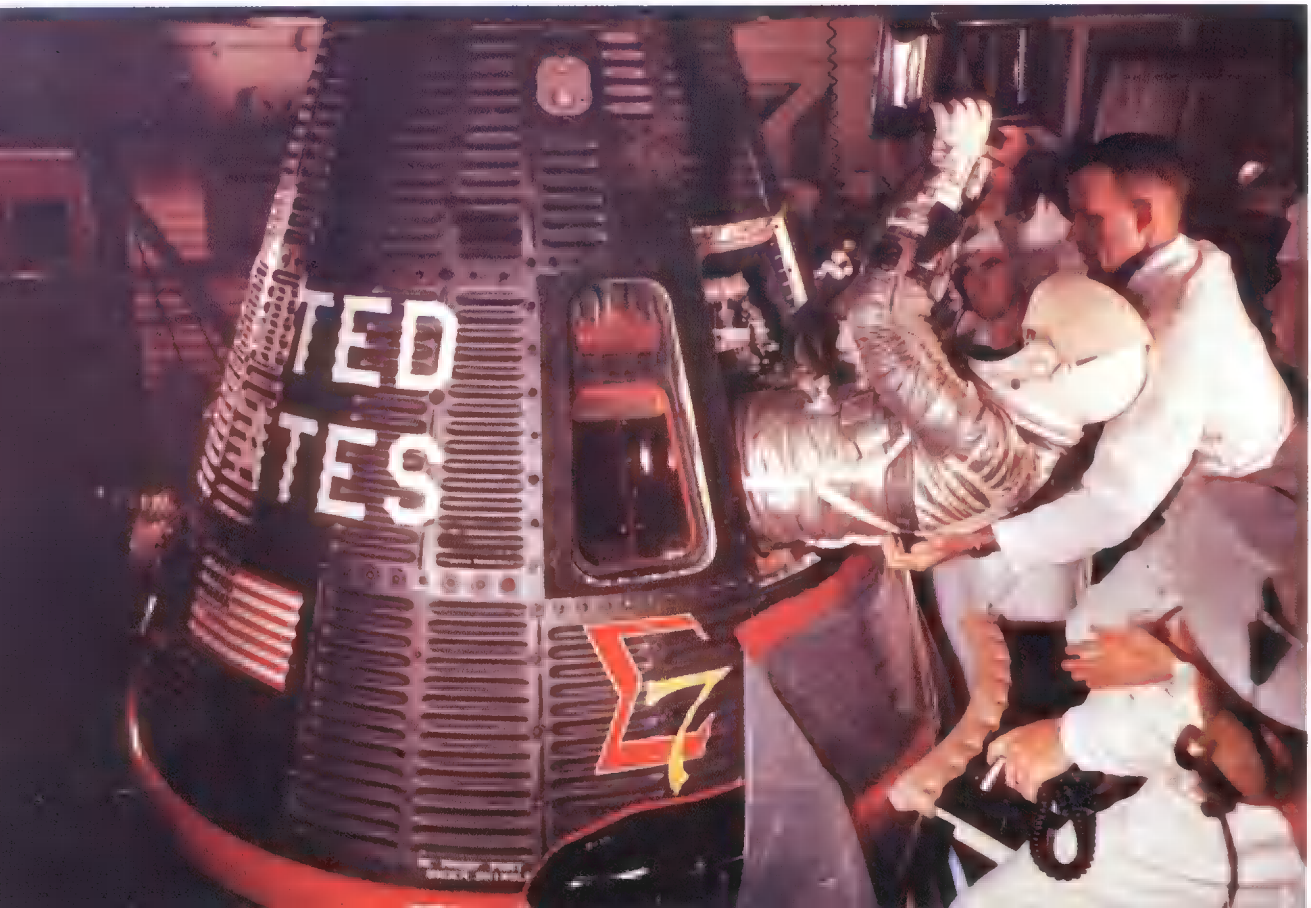
Most people think of astronauts as having a great time flying space vehicles, piloting the shuttle and drifting weightless in orbit. After all, some even get to the moon. Others get exciting jobs like rescuing satellites or repairing crippled spacecraft. In reality, it is much harder work than it sounds. Being selected as an astronaut means long hours in the classroom and a great deal of training.

The first astronauts were chosen in April, 1959, to go up in NASA's first manned capsule. Called *Mercury*, it had very little room and was so small it could almost have stood on the flight deck of the shuttle. No one knew what to expect when men first went into space. For that reason, the medical requirements were very strict, and special training devices put astronauts through physically rigorous tests.

The *Mercury* astronauts had to be under 40 years of age, less than 5 feet, 11 inches tall, be in excellent physical condition, and be a qualified jet pilot. They had to have a degree in engineering, be a graduate of a test pilot school, and have at least 1,500 hours of flying time. The seven men chosen for the Mercury program were an elite group whose names will always be remembered: Shepard, Grissom, Glenn, Carpenter, Schirra, Cooper, and Slayton.

The first manned flights were not as strenuous

The first manned space capsule, *Mercury*, was a tiny spacecraft designed to carry one pilot on flights lasting up to 34 hours in earth orbit.



as some physicians thought. The requirements were gradually relaxed over the following years when more groups were chosen. Extra pilots were recruited in a total of 11 separate classes. Two of the group were science astronauts. Chosen for their scientific skills rather than flight experience, they would not have command of a spacecraft. Only professional pilots could become commanders. Today shuttle astronauts fall into three separate categories: pilot astronauts, mission specialists, and payload specialists.

Two pilot astronauts fly each shuttle, controlling it during launch and landing. Pilot astronauts can serve as either pilots, in the right seat, or commanders, in the left seat. On orbit, the pilot has several other duties to help run the mission. The commander has charge of the flight and all personnel aboard the vehicle. Commanders graduate from a pool of experienced pilots and must have flown at least one shuttle mission.

Qualifications for pilot astronauts include a bachelor's degree in engineering, biology, the

There was very little room to maneuver inside *Mercury*. Each astronaut had about half the space available in a telephone booth.

By comparison, the shuttle orbiter is spacious and provides ample room on the flight deck for two pilots.

Mission specialists must carry out a variety of duties not associated with flying the shuttle. Sometimes mission specialists make space walks to conduct experiments in orbit.

physical sciences, or mathematics. A minimum flight time of 1,000 hours as a pilot-in-command on jet planes is essential. The applicant must pass a severe medical check and have good eyesight, blood pressure, and hearing. Shuttle pilot astronauts are the only group that will ever sit in the two front seats during launch and landing.

The next category of astronauts is that of the mission specialist. Their job is to look after experiments, tests, mission operations such as space walks and satellite repair, and scientific instruments in the payload bay or the crew compartment. In addition to a degree, they must have had experience in some form of research. Physical requirements are not as strict as they are for pilot astronauts.

NASA astronauts are recruited by the Johnson Space Center (JSC) near Houston, Texas. The astronauts are based there and use many different training facilities to keep themselves fit and to learn about new spacecraft and equipment they will have to use. The exact number of astronauts changes from time to time. Since first selected, 48 have left the program and 15 have died.

In 1986, NASA had 94 astronauts on the payroll, out of 157 that had been selected since

NASA's Johnson Space Center, alongside Clear Lake near Houston, Texas, is a place where all United States astronauts prepare for space missions and rehearse the many duties they must perform in orbit.

Part of an astronaut's training is rehearsal for the unexpected, including ditching at sea, where they may have to survive alone for several hours.

the first group in 1959. Of those 94, 52 are pilot astronauts and 42 are mission specialists. Since May, 1961, up to and including the last *Challenger* flight, 152 people had been launched aboard NASA spacecraft, 132 of which were career astronauts. Of that total, 96 have flown the shuttle.

Astronauts in the third category, payload specialists, are not career astronauts. They are a group that fall outside the 94 existing astronauts based at JSC. Payload specialists are people who do not normally fly in space but have some special reason for making one or more trips. They are the only group who need not be U.S. citizens. They may be included because they have some vital experiment to conduct. One example is McDonnell Douglas employee Charles Walker, who has developed a machine for making better drugs in space. He has made three trips in the shuttle.

Up to the tragic loss of *Challenger* in January, 1986, twenty payload specialists had flown in the shuttle. One of the *Challenger*'s crew, Gregory Jarvis, was a payload specialist from Hughes Aircraft Company. He wanted to carry out an experiment in space to see how weightlessness affected the movement of liquids. Because the shuttle can carry up to eight people, NASA wanted to add another group who would go only once and have no responsibility

for mission operations or experiments. They were to have been people who could provide some advantage for others by going into orbit.

This type of traveler was called a space flight participant. Teacher Christa McAuliffe was to have been the first. Had she not been killed when *Challenger* blew up, she would have conducted classroom lessons from space to teach children about weightlessness. Another space flight participant was to have been a journalist. He or she would have written about space travel and helped communicate to people everywhere the wonders of orbital flight by first-hand experience. It is uncertain whether space flight participants will be allowed to fly in the future.

Whether space flight participant, payload specialist, mission specialist, or pilot astronaut, simply being chosen for the program requires a great deal of effort. When NASA announces a recruiting campaign, several hundred people

In order to simulate the weightlessness of space, a huge water tank at the Johnson Space Center has been used to train astronauts.

Weighted down to achieve buoyancy so they neither sink nor rise, astronauts carry out operations they expect to perform in space.

apply. Only a few get through the tests and examinations, which are aimed at finding the best people for the job. Educational requirements are high but not the only important qualification. Another is the ability to do well at new tasks.

Because shuttle crews live together in space, they must get along well with each other. They must be tolerant and work well in a group. Just as important, they must be able to understand each other and work well as a team. One individual should not be aggressive or stand apart from the rest. All these factors are considered when people apply to become astronauts.

Once selected, a candidate moves to the Johnson Space Center and begins classroom work. All candidates must brush up on mathematics, basic science, meteorology, navigation, astronomy, physics, and computer sciences. They must learn new technologies and

If the astronauts should have to escape from a shuttle that threatens to explode, they would be carried away in a vehicle like this converted armored carrier.

receive instruction in space flight operations. This involves learning all about the shuttle and what makes it operate. Tours of the launch pads and control centers at Cape Canaveral follow instruction about how the missions are controlled from Houston.

New astronauts learn about safety on the shuttle and about rescue procedures should something go wrong. They must understand what equipment the shuttle carries to put out fires or to save lives if the orbiter ditches at sea. Then astronauts are given a feel for space flight in *simulators*, mechanical devices that behave like the real thing and imitate launch and landing. To get the feel for going outside a spacecraft, astronauts wear space suits and train in giant water tanks. This helps support them and simulates weightlessness.

Flying in a KC-135 airplane, the astronauts get several seconds of weightlessness in which to practice difficult operations like putting on a space suit in orbit.

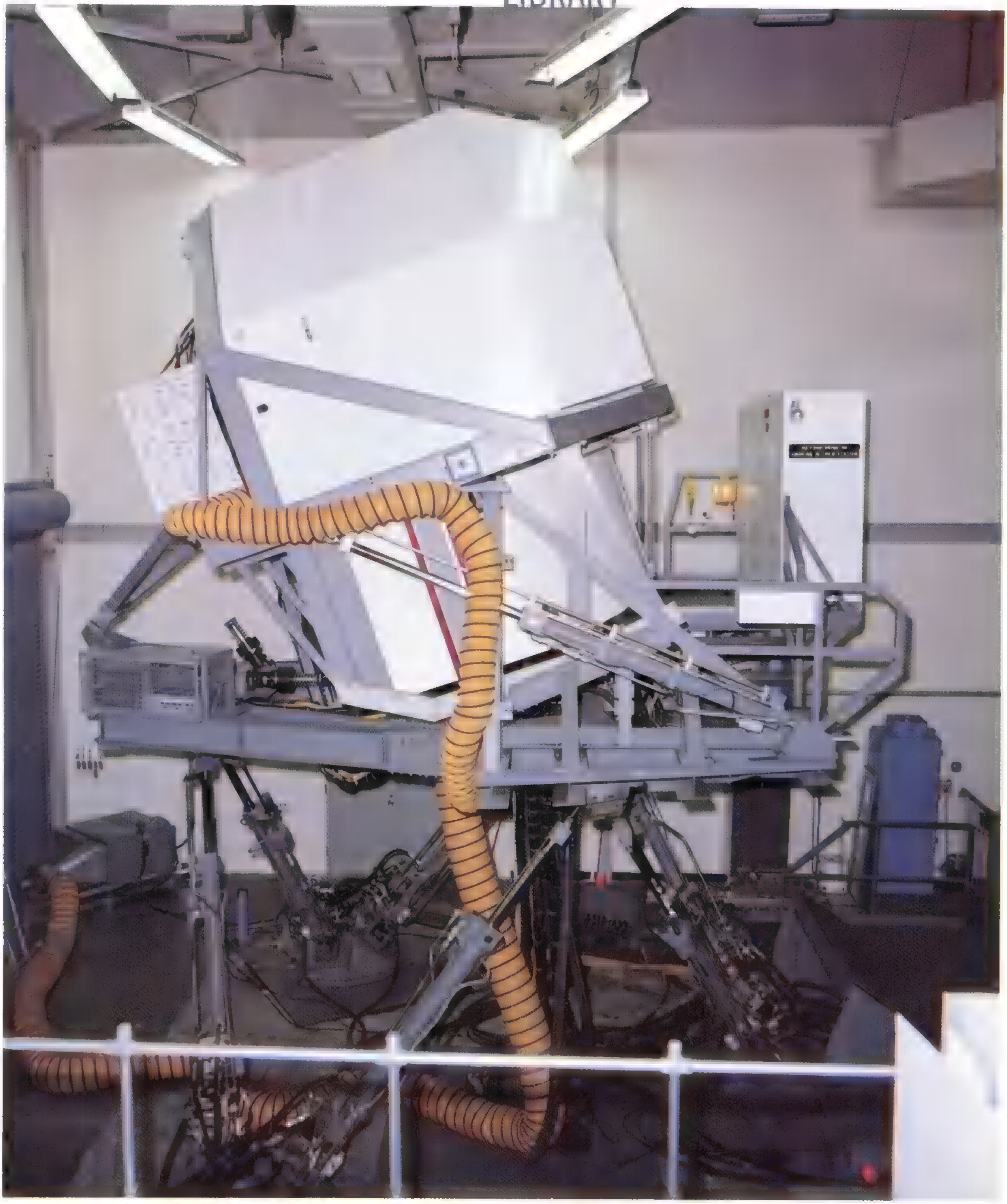
To experience actual weightlessness, new astronauts spend time in a specially equipped plane that flies a high arching curve through the air. Like taking a fast start on an elevator, everything inside the plane becomes weightless for about a half-minute. Flights like this help astronauts practice putting their space suits on and taking them off again. It is also useful for practicing difficult jobs, such as conducting complicated experiments.

Pilot astronauts must keep up their flying skills by regularly piloting airplanes. NASA keeps Northrop T-38 jets to visit launch sites, space centers, and aerospace companies around the country. These jets are based at Ellington Air Force Base, close to the Johnson Space Center. Pilots get the feel for handling big planes by using an Air Force KC-135 jet tanker transporter. To practice landing a shuttle, pilot astronauts use a specially modified Grumman Gulfstream.

The shuttle is built to slow down as it returns to Earth through the atmosphere. That means it flies very differently from a normal plane. It approaches the runway at a very steep angle and levels off just a few hundred feet above the ground. Pilot astronauts spend many hours practicing these difficult approach maneuvers. The Gulfstream looks nothing like the shuttle, but it handles in almost the same way and provides a realistic double.

NASA has no strict rules about exercise but requires that astronauts keep fit. People differ in the amount of exercise needed to stay in shape. The stress of acceleration in shuttle missions is only one-fifth the acceleration felt by early *Mercury* pilots. Astronauts no longer need to be super-fit. Gymnasium facilities exist at the Johnson Center for a workout any time. Within about eighteen months, candidate astronauts can be selected for a space mission. Experienced commanders will choose people they think are ready for flight. Those astronauts will then face their biggest test of all.

The Grumman Gulfstream is used to train pilots to land the shuttle and has been modified to give it the same flying characteristics.



This strange-looking box is a shuttle simulator. Inside it looks exactly like a shuttle orbiter, and it can be moved around to give the crew a feeling of motion.

The Flight Deck

The shuttle crew compartment is at the front of the orbiter so that pilots can see to land it like an airplane. The compartment is divided into two areas. The mid-deck area is entered through a hatch in the side of the orbiter. It can hold up to four collapsible seats and has one window in the center of the hatch. Above the mid-deck is the flight deck, arranged in a way very similar to the flight deck of a plane. It has the familiar arrangement of two seats for the two pilots facing forward but also two seats behind. Front and side windows give a good view all around. A single ladder allows access to the flight deck from the mid-deck below. In space, astronauts can drift between the two areas in their more comfortable weightless state.

A tour of the crew compartment might begin at the mid-deck. This is where the astronaut first

Just inside the orbiter access hatch (to the right) lies the crew toilet and personal hygiene station.

Many lockers in the mid-deck area are used to carry personal equipment for the astronauts and sometimes experiments for scientists to perform in space.

steps into the shuttle through the circular 40-inch hatch. Inside are the living quarters astronauts will use to sleep, eat, wash, and perform their personal hygiene. The area is about 10 feet long and 12 feet wide at the back and decreases to 9 feet, 6 inches at the front, where it fits into the shuttle's nose section The mid-deck has a height of about 6 feet, 10 inches.

The mid-deck is a small room crowded with equipment packed in to support the flight. Biggest of all is the airlock fixed to the rear wall, through which suited astronauts will move for space walks. The airlock is a large drum-shaped cylinder nearly 6 feet across. It has one hatch facing into the mid-deck and one facing out through the rear wall. Space suits are kept in the airlock, and two astronauts can isolate themselves inside and close the hatch. Then they can depressurize the interior, open the outer hatch, and drift into the cargo bay.

The galley is attached to the wall of the mid-deck alongside the main hatch. It is a combination kitchen, food stowage area, water dispenser, and pantry. Meal trays are stowed in a special place where one crew member can prepare food for all the crew. Drink cups, condiments, utensils, and paper towels are also available. It takes less than one hour to prepare a full meal for seven people. The menu is varied, and each astronaut gets about 3,000 calories a day.

Mealtime brings out the food trays, separately prepared in a galley and, as seen here, attached to the lockers for individual crew members.

Provisions for sleeping are limited and can be one of two types. On some flights, only hammocks strung between lockers are available. On other missions, a rigid sleep box is carried, where astronauts can rest in boxes stacked against the wall. Ear plugs and eye shades are standard equipment. The personal hygiene station provides water for washing, a mirror with light, soap dispenser, and wash cloths. On some flights the personal hygiene station is part of the galley unit.

Personal lockers are attached to the front and rear walls. Clothing, medical supplies, and some experiments are contained in drawers for easy access. A limited health-care pack is available for sick astronauts, as are drugs with various items of equipment like scissors, tweezers, syringes, and forceps.

Above the mid-deck is the flight deck. From here, the shuttle is controlled and astronauts monitor the orbiter's many systems and items of equipment. The flight deck contains all the instruments, computers, and controls necessary to operate the vehicle during flight.

Above the mid-deck is the flight deck, where the two pilots control the Shuttle during launch and landing and operate its many systems to keep it working in space.

Although the orbiter is in free drift as it circles the earth, the astronauts must do many jobs to keep all the systems running and working properly in case of an emergency.

The two pilot seats are adjustable for comfort and placed so that each crew member can easily reach controls on a main display panel in front, similar panels on either side, and a central console between the two.

Unlike earlier spacecraft, the shuttle has computer consoles and display screens that provide more information than the dials and meters on previous vehicles. There are four general-purpose computers and one back-up.

Much practice goes into a space mission before the actual flight. Here an astronaut practices in the simulator, spending what will be many hundreds of hours becoming familiar with everything inside the vehicle and how it works.

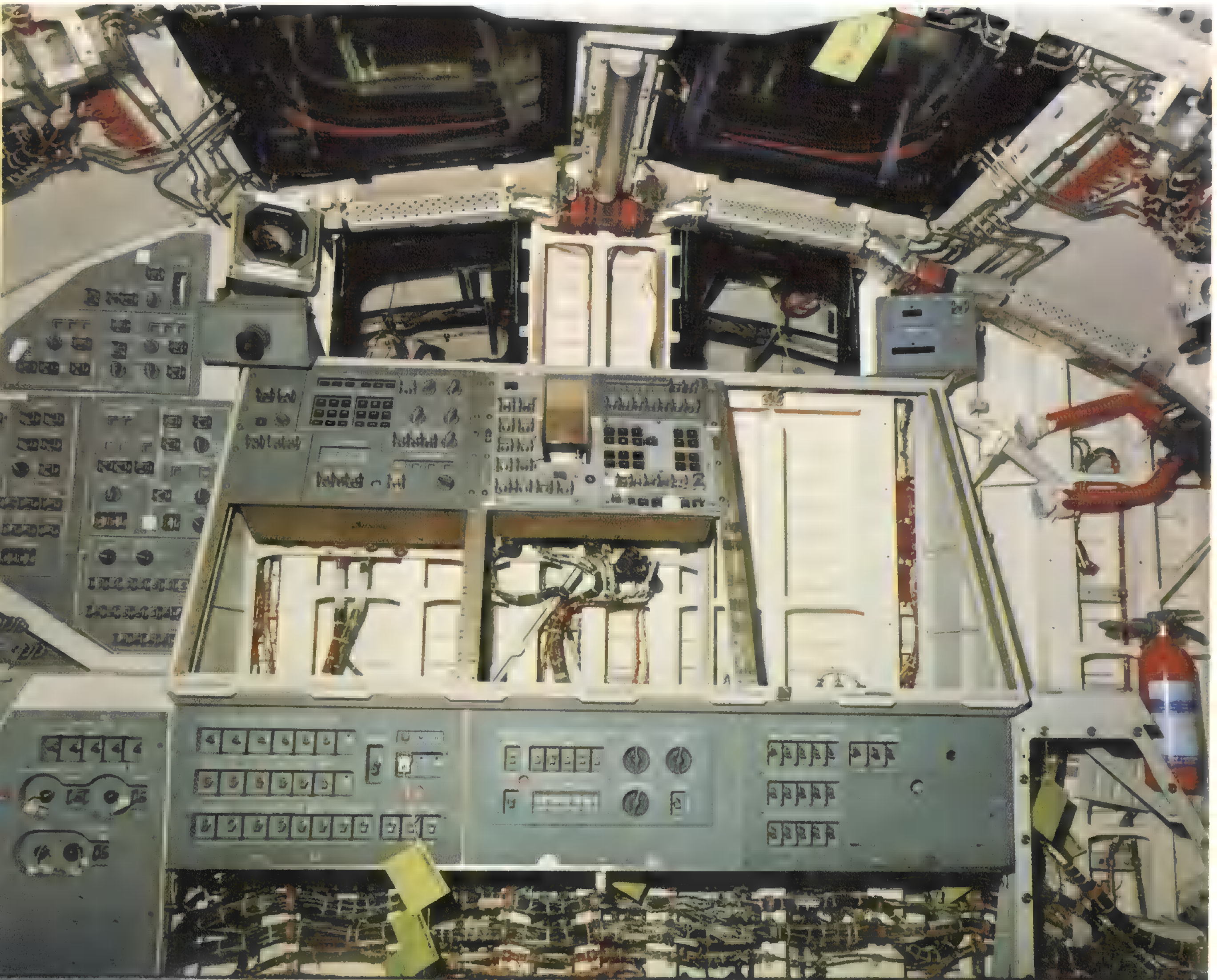
With many different programs stored in their memories, the five computers watch every part of the shuttle's many systems. At any time a pilot can ask the computer to tell him the status of vital parts in the vehicle. This capability helps cut down the number of dials and instruments, making more room for other equipment. If each item of information provided to the pilots was shown through a different dial, there would be no room left for the crew.

Although computers help by speeding up the flow of information and reducing the number of dials, they cannot replace some important switches and knobs. These switches and knobs control communication channels that carry voice and TV signals to the ground and other signals back to the shuttle from mission control. Others control the electrical system and allow astronauts to switch power to different systems and experiments. Some controls for the environmental system keep the crew compartment warm and at the correct pressure; others for the cooling system remove unwanted heat from electrical equipment.

Pilot systems are in the forward flight deck. Other control panels for the missions specialists and payload specialists are in the aft flight deck facing the cargo bay. These are used to control TV cameras outside in the bay, operate the shuttle's robot arm, switch experiments on and off, and stow scientific equipment. Two windows in the aft flight deck wall provide a view into the cargo bay. Two more windows in the ceiling allow a view straight up through the cabin roof. The roof also provides a way out if the shuttle should have to ditch at sea. Special panels can be removed that would allow the crew to escape up and over the side.

Left: The fire extinguisher must be used to put fires out quickly. It contains a pipe which can be fixed to any one of several ports and leads to channels behind the control panels where foam will quench the fire.

Below: Facing directly back from the flight deck is the aft crew station. Through two windows in the bulkhead, it looks directly into the payload bay or, with two other windows in the ceiling, directly into space.



Flying the Shuttle

Preparing the shuttle for flight takes a long time. There are many things to do, and they must all be done in a very precise sequence, called a *countdown*. The countdown is based on launch time to the exact hour, minute, and second. Launch time is called T-0 (zero). To allow time to correct things that might go wrong as the shuttle is being prepared for flight, the countdown has a number of holds, where the clock is stopped for a fixed period.

The first important event is filling the big external tank with propellants. This begins about 8 hours and 10 minutes before launch, just after the fuel cells have been started. Fuel cells produce electricity by bringing hydrogen and oxygen together in a special device. All power aboard the shuttle is produced this way, with water as a by-product. Hydrogen and oxygen are contained in special tanks at the bottom of the cargo bay.

Nearly three hours are needed to fill the big external tank with the fuel to be used by the main engines in reaching orbit. Liquid oxygen in the tank must be kept extremely cold. It boils at -297° F. Liquid hydrogen boils at -423°F. The big external tank is like a huge thermos bottle. If it did not have special insulation, ice would form around it.

The astronauts are driven to the launch pad about 2 hours before launch. They do not wear space suits because the shuttle, like an airliner,

Preparation for a mission includes the traditional pre-launch breakfast, when the flight crew has its final meeting with the press and the public.

has a pressurized atmosphere. Space suits are used only when the crew go outside in orbit. It does not take astronauts long to get ready for a flight. Depending on the number of astronauts, they can usually climb inside and strap themselves in within about 20 minutes. Some flights have carried up to eight people.

About 1 hour and 40 minutes before launch, the side hatch is closed and locked. A leak check is carried out to make sure there are no gaps in the seal. This check is done by raising the pressure of the cabin to a point just above the pressure of the outside atmosphere. If the pressure starts to drop, there is a leak. If not, the seal is tight.

Outside, chase planes get ready for flight from Patrick Air Force Base, a few miles south

With little more than two hours to go before launch, the crew arrives at launch complex 39 and rides to the top of the launch tower in a special elevator.

The crew members practice getting in and out of the shuttle many times before a flight. Here they are seen returning from a simulation, but they will walk this route on the day of launch.

of Cape Canaveral. They will take off 9 minutes before the shuttle lifts off and follow it for the first minute or so, taking pictures all the time. Rescue helicopters stand by in case they are needed, and weather reports flow continuously to the launch director. He alone is responsible for giving the "go" to launch.

All the major events in the long countdown are controlled by computer, but there are places where the ground crew can stop the launch at any time. As the minutes tick away, ground crew members are busy at many separate tasks. They set up the proper computer programs for launch and check that mission control in Houston is

The shuttle is capable of carrying a maximum of about eight crew members. The four here are on the flight deck, with the two pilots directly behind the forward windows.

Up to four crew members can be housed in the mid-deck area, below the flight deck seen here through the exit hatch. This is the last view of the crew before lift-off.

receiving data from the shuttle about its systems. They will continually monitor the shuttle in space and track carefully every second the actions of the crew at the main console.

The last countdown hold comes 9 minutes before launch. When it picks up and the seconds tick away to zero, final preparations take place. At 7 minutes the access arm along which the crew walked to climb aboard the shuttle is retracted. In an emergency it can be moved back in 15 seconds. The crew would escape across this if something went wrong and the shuttle threatened to explode.

With just 5 minutes to go, the ground crew starts the two auxiliary power units (APUs). These are located back in the tail section and provide hydraulic power to operate the flight controls on the wings, the main and nose landing gear and doors, the tail rudder, and swiveling movement in the main engines. The engines must be swiveled to keep them pointing precisely in the right direction. This produces the same effect as gently moving the wheel of a car left and right to keep it pointing in a straight line.

At the same time the APUs start, the two boosters are armed, ready for ignition. At 3 minutes 30 seconds, the ground power supply is disconnected. Up to this point, the shuttle has shared electrical power between its own fuel cells and an outside source. Now it is on its own. The astronauts also carry out a check of the control surfaces and the rudder to make sure they work and are getting hydraulic pressure from the APUs.

At 2 minutes 55 seconds, a cap (called the beanie cap because it looks like that kind of hat) fitted over the top of the big external tank is lifted off and retracted. It has been used to blow warm air over the tank and prevent ice buildup. The shuttle orbiter has thousands of small tiles to protect it from the heat of re-entry. Large chunks of ice shaken free at launch could damage them.

With 31 seconds to go, the four main shuttle computers take over control of the countdown. From this point on, only one ground command is needed. "Go for main engine start," at about 6.6 seconds before liftoff. At 21 seconds before liftoff the three main engines are swiveled to show they can move properly to control the direction of flight. At 10 seconds, sparklers underneath the three main engine nozzles are ignited to burn away any hydrogen that has built up. This gas is invisible and could explode when the engines ignite.

At precisely 6.6 seconds to go in the countdown, the command is given and the three main engines ignite, tipping the vehicle over at the nose before it springs back. In the cockpit, the

Little more than six seconds before launch, the three main engines ignite. The shuttle rapidly rises from its pad when the two boosters are fired at zero in the countdown.

crew are suddenly pitched forward about 17 inches as they feel a low rumble like a distant locomotive. Suddenly, at zero, the two huge solid boosters start up and the astronauts get a tremendous kick in the back. The shuttle is on its way, climbing up into the sky with increasing acceleration.

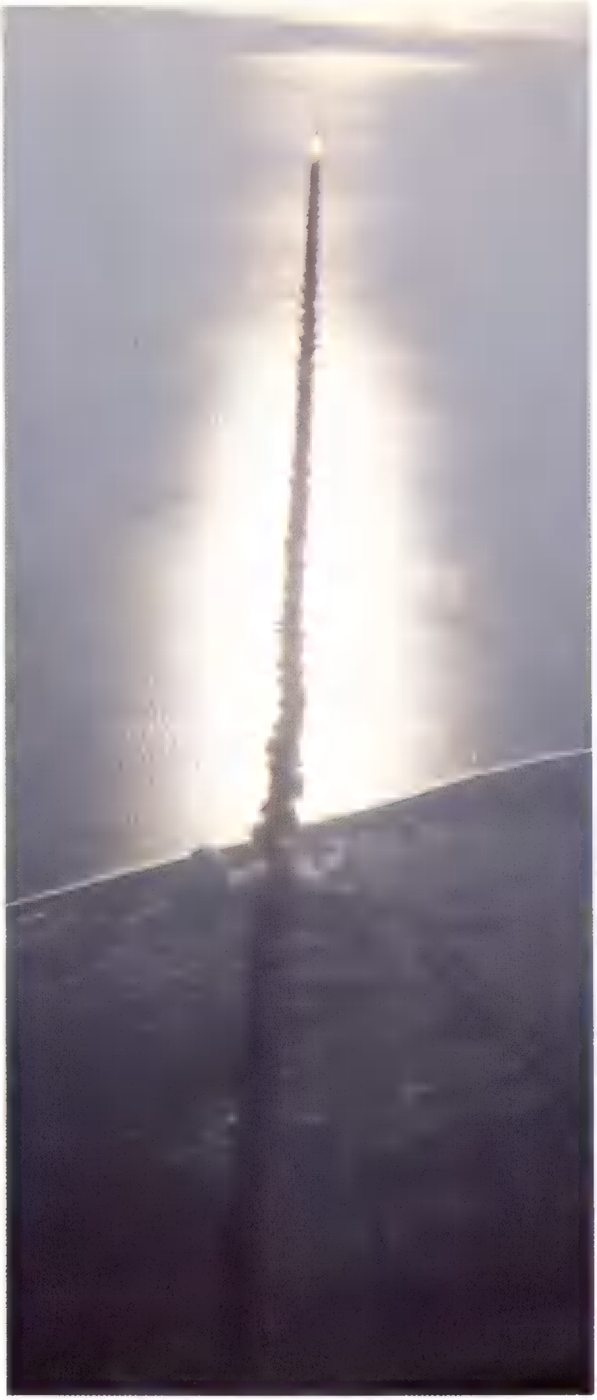
On the flight deck, vibration from the booster rattles and shakes the crew compartment as astronauts bounce around in their seats. Some grab the nearest thing and hold on to steady themselves. Outside it all looks smooth, while inside it is a bumpy, rocking ride. At about 7 seconds, the shuttle rolls around to its proper

Thrusting rapidly upward on the combined energy of three liquid engines and two solid motors, the shuttle soon reaches an acceleration where the engines must be throttled down to maintain safe limits.

As the shuttle ascends, many systems aboard the vehicle transmit data to the ground, where engineers continually watch for signs of a problem during the flight.

heading, putting the crew upside down as it thunders on and up, arching over on its back. To the crew this is not as noticeable as it might seem. The only real difference is that the horizon comes down from the top of the forward windows rather than up from the bottom!

About 1 minute into the flight, the shuttle goes through the most severe stresses. At this point, the maximum air pressure is pushing on the front of the shuttle. As it climbs higher, though, the pressure will decrease and the vehicle will accelerate. Comfort and relief comes at just over 2 minutes into the mission, when the boosters use up all their fuel and separate from the external tank. Suddenly, all the vibration goes, the noise level drops, and the ride is a smooth trip for the next 6 minutes.



Astronaut John Young took this magnificent view of the *Discovery* as it thundered from the launch pad at Cape Canaveral in August, 1984.

At about 7 minutes 30 seconds, depending on the mission, the three main engines are throttled back to prevent a buildup in acceleration. The weight of the shuttle is becoming less as it consumes fuel and flies higher and faster. At several points the crew change computer programs to give the shuttle the instructions for the guidance system to steer it on a proper course. For most of this time, the pilots are watching the displays and throwing appropriate switches to change these programs.

During the flight into orbit, crew members have the option of aborting the mission at any time. This can be done in one of several ways, depending on where the shuttle is in its flight path. Just after the point where the boosters are dropped off, the shuttle has the option of aborting the flight to orbit, dumping the external tank, and gliding to Earth on the other side of the Atlantic Ocean. Depending on the mission, it can land in either Africa or Spain. An abort like this might be necessary if one of the main engines shuts down.

At about 4 minutes 30 seconds, the shuttle

All the way up into space, the flight crew monitor many systems throughout the vehicle. Although much of the sequence is automated, the crew stands ready to take over at any time should something go wrong.

During the long climb into orbit, the astronauts can abort the mission at any time. This is the abort switch which allows the pilot to change the particular type of abort at various stages of the launch.

loses the option of turning around and flying back to a runway at Cape Canaveral. From this point on it is too far out to return to Florida safely. If an engine failed, the shuttle would still be better off pressing on into orbit using the other two engines. An alternative would be to head for a complete trip around the globe, landing at Edwards Air Force Base in California. To do this, the shuttle would fly into space and then reenter as though it were returning from a normal mission.

About 8 minutes after launch, the shuttle reaches a speed of just over 17,500 MPH and a height of just over 60 miles. The crew watches the instruments as the engines prepare to shut down. Suddenly, the astronauts are pitched forward in their seat straps. They feel as if they are falling forward and back down to Earth. The shuttle and its crew are weightless, but not yet in orbit.

About 18 seconds after the three main engines shut down, the external tank is separated from the orbiter. It has burned almost all its propellants in the shuttle engines and is now of no further use. On the flight deck, the crew feel loud thumps like rubber hammers on a

tin can. This is the sound of the explosive bolts firing apart to free the tank. The orbiter drifts up to its peak height of 160 miles or so, and the crew fires two maneuvering rockets on either side of the tail for about 2 minutes. This adds speed to make the path circular. The shuttle is now in orbit.

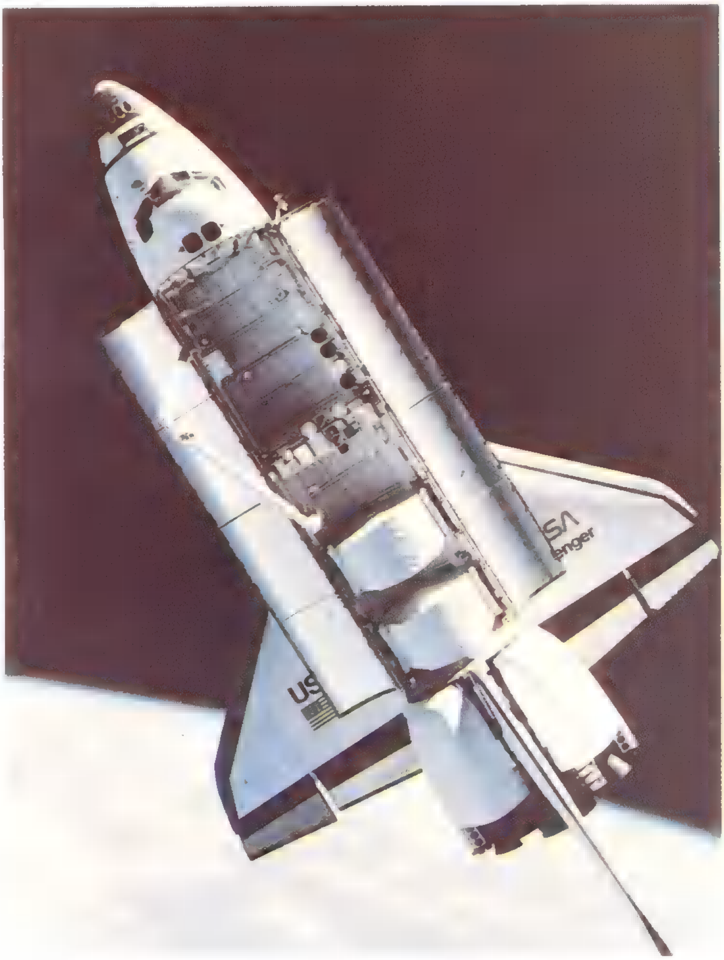
When the shuttle gets into orbit, the pilot's work begins, and so do the "housekeeping" chores that are essential to keep the spacecraft in good health and fit working order.

Return to Earth

Control of the shuttle's flight path between launch and orbit is fully automatic. If something should go wrong, or the commander suspects there is a problem, either pilot can use manual controls. Swiveling the engine nozzles at the back of the orbiter and on the two solid boosters can be done manually through a hand controller. This works like a pilot's control stick in a fighter plane. Pulling the stick back puts the nose up, pushing it forward puts it down. Tilting it to left or right causes the shuttle to fly left or right.

To throttle the main engines, the pilot uses a handle that works like the throttle on a plane. For full throttle, the handle is forward. Power is reduced by pulling back on the handle. Shuttle engines can be throttled back to 65 percent of their normal output, which helps to reduce the level of acceleration.

When the shuttle reaches orbit, the pilots



In order to radiate excess heat to space, the two big payload doors have radiators on their inner surfaces.

A lot of mission time is spent taking equipment out and putting it away after each experiment. Many tasks must be carried out in accordance with a formal written flight plan.

prepare the vehicle for several days of activity, first opening the cargo bay doors. Radiators remove unwanted heat from the electronic equipment aboard the shuttle and radiate it to the cold of space through pipes on the inside surface of each door. If the doors cannot be opened, the shuttle will have to return to Earth.

The shuttle does not have to remain in a fixed attitude in space as an airplane does in the atmosphere. An airplane gets lift from its wings and must point in the direction it is going. A spacecraft remains in orbit without lift. It controls its attitude, or direction, with small rocket motors called thrusters. The shuttle has 38 thruster motors clustered in the nose and in two pods, one on each side of the vertical tail.

The attitude thrusters can be used alone or in pairs to make the shuttle rotate around its center. It can pitch its nose up or down, left or right, and spin round slowly like a top. The thrusters are arranged in such a way that the vehicle can twist and turn in any attitude. In this way it is made to face Earth, space, the sun, or anything else.

To change its position in space, these motors are used together to shunt the shuttle backwards, forwards, up, down, to the left, or to the right. Each of the two pilots has a special control unit for this purpose. To raise or lower the orbit by several miles, the two maneuvering engines used to put the shuttle in orbit are fired up.

When the time comes to return to Earth, the

The best views from the shuttle are through the forward windows up on the flight deck, seen here across the back of the commander's left forward facing seat.

shuttle uses these two maneuvering engines to slow down. In this way, Earth's gravity overcomes the forward speed of the shuttle and it gradually descends toward the atmosphere. This activity is called the de-orbit burn and takes place over the Indian Ocean for a landing on the West Coast, or over the Pacific Ocean for a landing back at Cape Canaveral. Most land ings take place at Edwards Air Force Base in California.

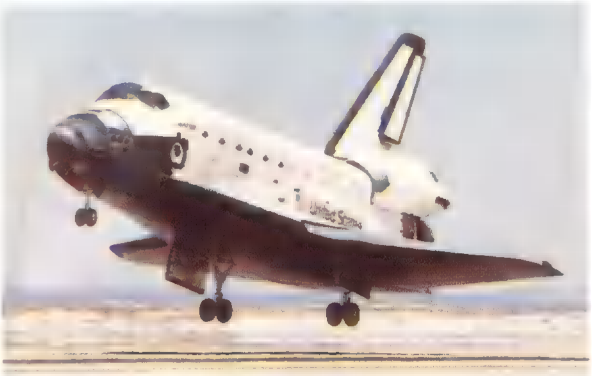
The shuttle is turned around to face backwards with its nose tilted down. This points the aft maneuvering engines up slightly for the correct attitude. The shuttle is slowed by about 200 MPH and then starts to fall toward the earth. In the next few minutes, the crew turns the orbiter round to face forward with the nose pitched up. The crew members return to their seats, strap in, and wait for re-entry.

The shuttle begins to feel the atmosphere at a height of about 76 miles. As the increasingly dense air starts to slow it down, it begins to get hot. The heat is caused by friction. The shuttle's metal skin is protected by more than 30,000 tiles made of a special material which will not burn at the temperatures reached during re-entry. In the cold of space the surface temperature can be as low as -250° F, rising to a maximum 3,000° F as the shuttle comes back.

When the shuttle reaches the outer edge of the atmosphere, it is moving at 24 times the speed of sound, expressed as Mach 24 (about 17,500 MPH). At this point it is more than one thousand miles west of Hawaii. As it slows, it is

Above: When the shuttle returns to Earth, it slows down by turning its rear end forward and firing two maneuvering engines, seen here during an orbit change in space.

Right: It takes about thirty minutes for the shuttle to come back from space through the atmosphere and land like an airplane on a conventional runway. Notice the twin wheel assembly on each landing leg.



The orbiter lands at just over 200 MPH and is controlled by an airbrake at the rear of the tail and by control surfaces on each wing.

covered by a hot gas generated through friction with the air which blocks radio waves. For about 16 minutes, mission control is out of touch, and no one knows if the shuttle has survived. When it slows, radio communication is possible once more.

As it crosses the coast of California, the shuttle's speed is down to Mach 7 and it is flying at a height of 27 miles. Passing north of Santa Barbara, it falls steeply toward Edwards Air Force Base. By this time the tiny thrusters are of no further use, and the hand controller is electrically switched to the flight control surfaces on the rear of the wings and on the tail. In this way, the shuttle converts from a spacecraft into a glider.

Heading east, the shuttle flies over Edwards at

After the spacecraft has been electrically shut down, the crew members leave the vehicle that has been their home for up to ten days.

53,000 feet, just above the speed of sound (675 MPH). It then begins a wide turn to the left around what is termed the *heading alignment circle.* This brings the vehicle back for a landing toward the west. When it straightens up, the shuttle starts a very steep approach to the edge of the runway and flattens out less than 1,000 feet up. Seconds later the crew puts out the main and nose landing wheels. The shuttle touches down at around 210 MPH and slowly rolls to a stop.

Astronauts differ on their impressions of space. Each has a memory of his or her favorite part of the mission. Most flights last between five and seven days, although some missions have lasted for as long as ten days. Although each astronaut has a different job to do, they all work as a team to make the mission a success. There is only one thing they all want to do when they land: turn right around and do it again!

Astronauts cannot resist having a final walk around their vehicle, where the effects of re-entry can be clearly seen on the black ceramic tiles. Note the thruster ports around the nose.

GLOSSARY

Countdown	A method of preparing for the flight of a rocket or a manned space vehicle by starting launch preparations timed to completion at the point of lift-off, which is known as zero.
Edwards Air Force Base	Located in the desert northeast of Los Angeles, shuttle pilots land their orbiters here when returning from space to the west coast of the United States.
External Tank	The huge propellant tank containing liquid hydrogen and liquid oxygen divided by a bulkhead inside.
Grumman Gulfstream	A specially modified Gulfstream is used by astronauts to simulate the steep angle of descent in the last few minutes before a shuttle touches down on the runway.
Heading Alignment Circle	An imaginary circle in the sky around which the shuttle flies until it reaches the proper position to begin its descent to a runway.
Johnson Space Center	The NASA manned space flight facility in Houston, Texas, from where all manned shuttle missions are controlled.
KC-135	The Boeing military tanker transport plane used by NASA for astronaut weightlessness simulation.
Northrop T-38	A small training plane bought from the Air Force for astronauts to use when traveling to and from the Johnson Space Center.
Orbiter	The shuttle orbiter is that part of the total vehicle that carries the crew and cargo into orbit. It has wings and a tailplane to land on a conventional runway.
Simulator	Any device that simulates specific conditions for the purposes of research or training operators such as pilots.
Solid Rocket Booster (SRB)	Each shuttle needs two solid rocket boosters to lift off the launch pad and help propel it into space for at least the first two minutes of flight.
Titan	The U.S. Air Force intercontinental ballistic missile developed during the early 1960s and adapted into a launch vehicle for large military satellites.

INDEX

Page numbers in *italics* refer to photographs or illustrations.

Aborting the mission 37-38
Airlock 25
Atlantis 10

Boeing 747 Jumbo Jet 9, *13*
Booster, shuttle 7-13

Cape Canaveral 32, 38
Challenger 7, 10, 18, 19
Columbia 10
Countdown 30-35

Discovery 10, *36*

Edwards Air Force Base 38, 42, 44
Enterprise 9
European Spacelab *9*

Jarvis, Gregory 18
Johnson Space Center *17*, 20, 22

McAuliffe, Christa 19
Meals in space 25
Mercury space capsule *14*, *15*, 22
Mission specialists 15, *17*, 19, 28

Orbiter, shuttle 7-13, 24, *44*

Payload specialists 15, 18-19, 28
Personal hygiene in space 24-26
Pilot astronauts 15-17, 19

Recruitment of astronauts 17, 19-20

Satellites 6, 7
Simulator 21, *23*, *28*
Sleeping in space 26
Solid rocket boosters 12
Space stations 6
Space suits 30, 31

Thrusters 41-44
Training of astronauts 20-23

Walker, Charles 18

Young, John 36

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